PATENT SPECIFICATION

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COMPLETE SPECIFICATION

Improvements relating to Heat-Resisting Alloys

We, THE MOND NICKEL COMPANY LIMITED, a British Company, of Thames House, Millbank, London, S.W.1, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

Various articles are exposed in use to contact with carbon or a carburising atmosphere for prolonged periods at high temperatures. The carburising conditions may be generated intentionally, e.g. for the hardening of steel, or incidently, e.g. in the treatment of carbonaceous gases and solids. It is known to make such articles from alloys consisting essentially of nickel, iron and chromium. The alloys used should resist absorption of carbon, and also should be free from embrittlement after prolonged heating in the temperature range of 650 to 900°C.

The present invention is based on the discovery that alloys containing nickel, chromium and iron in critical ranges satisfy the requirements better than the alloys hitherto used.

The alloys used according to the invention contain from 40 to 50% (preferably from 41 to 47%) nickel and from 27.5 to 33% (preferably from 28 to 32%) chromium. They also contain from 0 to 0.5% carbon, from 0 to 1.5% silicon, from 0 to 2% manganese, and from 0 to 0.2% nitrogen, with the balance iron except for impurities and residual deoxidising elements. Preferably the carbon content does not exceed 0.2%, the silicon content does not exceed 0.75% and the manganese content does not exceed 1%. Among possible impurities is copper, the content of which should not exceed 0.4%.

It has been found that, when heat-ressisting alloys are compared under identical condlitions of exposure, the resistance to absorption of carbon is largely dependent upon the chromium content and increases with the chromium content. On the other hand since chromium tends to form an embrittling sigma phase when the alloy is subjected to prolonged heating, a high chromium content alone (at least 27.5%) is unsatisfactory. The ideal alloy for the purpose would be wholly austenitic, but it has been found that to suppress any ferritic phase altogether requires so high a nickel content as to render the alloy too low in iron and too expensive. If, however, the nickel content is made as high as 40% but not more than 50%, the embrittling sigma phase is suppressed and replaced by a ferritic phase high in chromium which is found not to be detrimental to the mechanical properties.

Nickel-chromium-iron alloys are commonly deoxidised by aluminium and titanium and contain residual amounts of these elements, say up to 1% titanium and up to 0.5% aluminium. In choosing the exact composition of an alloy for use according to the invention, regard should be paid to the probable presence of these residual deoxidants, since both titanium and aluminium are strong ferrite formers. Accordingly the nickel content should be slightly higher when titanium and aluminium are present than when they are absent, as will be the case if deoxidation is effected solely by, for example, calcium and silicon.

Three examples of alloys used according to the invention are as follows:

[*Price 3s. 6d.*]

	A	B	C
Chromium	28.5	28.63	31..22
Nickel	42	42.71	41..76
Titanium	—	1.06	01.4
Aluminium	—	0.45	01.38
Silicon	0.5	0.64	01.61
Carbon	0.1	0.05	01.07
Manganese	1	0.85	01.81
Nitrogen	0.1	0.057	01.055
Iron	Balance	Balance	Balamce

The presence of any embrittling phase after prolonged heating is shown by impact tests. The results of such tests in a Charpy machine on various alloys used according to this invention and also on an alloy containing 20% nickel and 25% chromium commonly used for the manufacture of the articles in question are given below. The tests were made on specimens in both the annealed and cold-worked conditions, all being heated at 800°C. in air but for different periods as indicated.

Alloy	Nominal Composition % Ni	% Cr	Charpy Impact in foot pounds after Hours	0	100	250	500	1000	3000
B	42.7	28.63	Annealed	56		36	34		
			Cold-Worked	28		28	31		
C	41.76	31.22	Annealed	52		—	33.55		
			Cold-Worked	29.5		—	25		
D	46	30	Annealed	48.5	51		43.55	44.5	43
			Cold-Worked	33	35		37	37.5	37.5
E	46	33	Annealed	50	37		36	38	41
			Cold-Worked	33	24		25	28	30
F	20	25	Annealed	79	33		14	11	9
			Cold-Worked	39	11		7	7	7

This table shows that alloys B to E used according to the invention are much superior to Alloy F, commonly used hitherto. Since the alloys were heated in air and not in a carburising atmosphere, the loss in ductility was the result of embrittling structural change and not of embrittlement by carburisation.

The resistance to absorption of carbon by alloys used according to the invention is shown by tests made with variouss alloys containing iron, nickel and chromium, all of which were subjected to 120 cycles of heating at 935°C. for 13 hours while packed in carbon, the specimens being oil-quenched at the end of each cycle. One alloy (H) according to the invention and four alloys (I to L) of other compositions were tested. The particulars are as follows:—

	Nominal Composition %				Carbon Content %		
	Ni	Cr	Fe	Si	Original	Final	Gain
H	42	30	26.5	0.5	0.10	0.19	0.09
I	78	15	16.5	0.5	0.04	0.31	0.27
J	35	21	44	—	0.10	1.28	1.18
K	35	15	47	3.0	0.07	1.48	1.41
L	20	25	55	—	0.11	0.78	0.67

A further advantage of the alloys used according to the invention is resistance to attack by sulphur, e.g. in the form of sulphur dioxide.

Another advantage is a reduction in the undesirable catalytic behaviour which nickel-chromium-iron alloys of higher nickel content may show when in contact with hot hydrocarbons as, for example, in furnace tubing used for the production of ethylene from ethane or propane. In addition the alloys used according to the invention also display resistance to an accelerated type of oxidation known as "green rot" oxidation which is encountered in alloys of higher nickel and lower chromium content.

Since the alloys have the properties set forth, the articles which are made from them according to the invention include furnace parts and apparatus subjected to carburising conditions such as carburising boxes, baskets and other fixtures for supporting articles to be carburised; cyanide pots and salt bath fixtures, wrought radiant tubes for use in a carburising atmosphere, and furnace tubing used for the production of ethylene from ethane and propane.

WHAT WE CLAIM IS:—

1. An article exposed in use to contact with carbon or a carburising atmosphere for prolonged periods at high temperatures made of an alloy containing from 40% to 50% nickel, 27.5% to 33% chromium, from 0 to 0.5% carbon, from 0 to 1.5% silicon, from 0 to 2% manganese and from 0 to 0.2% nitrogen, with the balance iron, except for impurities and residual deoxidising elements.

2. An article according to claim 1 in which the alloy contains from 41% to 47% nickel, from 28% to 32% chromium, not more than 0.2% carbon, not more than 0.75% silicon and not more than 1% manganese.

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